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Consequences of Local Government Involvement in the Icelandic ITQ Market

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Abstract *This paper gives an account of the development of fishery regulation and management in Iceland, including the development of cod stocks, and the fishing fleet in Iceland since 1945. There was considerable experimentation with fishery management systems in Iceland beginning in 1975. Many economists and others predicted that the fishing fleet would be reduced as a result of the new regimes, but this has not happened to the extent anticipated. Local governments have traditionally had a stake in the Icelandic fisheries. The motives of local municipalities might conflict with the motives pursued by the fishery managers. A theoretical model is developed to understand the consequences of local politicians' involvement in the quota market. Furthermore, it is indicated that the degree of ease with which the less effective fishing firms find ways to circumvent the profitability consequences of the management regime depends on the initial allocation of fishing rights.*

Key words Fishing fleet capacity, fishing fleet regulation, ITQs, local communities.

Introduction

Considerable experimentation with fishery management systems in Iceland began in 1975. Many economists and others predicted a reduction in the size of the fishing fleet under the new regimes, but this has not happened to the extent hoped for. In addition, local governments have traditionally had a stake in the Icelandic fisheries. The reasons for their involvement include job security and enhancement of economic activity in the local community. Such motives might conflict with the goals pursued by the fishery manager.

This paper reviews the development of fishery regulation and management in Iceland and considers the development of the cod stocks and the fishing fleet in Iceland since 1945. A theoretical model is developed to understand the consequences of local politicians' involvement in the quota market. It is concluded that such involvement in the fisheries would reduce the efficiency of Individual Transferable Quota (ITQ) fishery management schemes. Furthermore, it is indicated that the degree of ease with which the less effective fishing firms find ways to circumvent the profitability consequences

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of the management regime depends on the initial allocation of fishing rights.

A review of fishery regulation and fishery management in Iceland from mid-century onward is first outlined, followed by an account of local community involvement in Icelandic fisheries since World War II. The section following this history contains a few thoughts on the connection between fishery management and fleet size. A model is then developed allowing for a heterogenous fleet of vessels. Finally, conclusions are presented.

Fishery Regulation and Fishery Management in Iceland

From medieval times until 1948 the regulation of fisheries in Icelandic waters was aimed mainly at limiting and specifying the type of gear allowable in order to avoid a "chaos of lines" and similar pitfalls of uncontrolled fishing. In the first half of the 20th century this policy was pursued by restricting the use of relatively advanced equipment (*e.g.*, bottom trawls and Danish seines, often used by foreigners) on the traditional fishing grounds of small vessels using traditional fishing equipment.[1] After 1948 the main goal of fishery management was to protect the spawning and feeding grounds of the demersal species, as well as to ensure that the gear used was more effective in catching older individuals.[2] In other words, the emphasis shifted from guarding the livelihood of the small-scale fishers and avoiding chaotic use of gear, to utilizing the growth potential of the demersal fish stocks more effectively.

In 1938 over 55% of the total catch in Icelandic waters was taken by foreign vessels.[3] The foreign vessels all but disappeared during World War II, but returned with increased catching power after the war. Consequently, reducing the foreign fishing effort then became the goal of Icelandic fishery management, with the hope of managing the natural resources in the waters around Iceland in a way that would strengthen the Icelandic economy. The extension of the fisheries limits from 4 to 12 nautical miles in 1958, from 12 to 50 miles in 1972, and from 50 to 200 miles in 1975 were steps toward that goal.

In 1975 the Marine Research Institute issued a report on the status of the Icelandic cod stocks. The report, nicknamed "The Black Report," stated that the Icelandic cod stocks would soon collapse if fishing continued at the same level of effort.[4] Several weeks later a working committee of the Governmental Science and Research Council published another report: "Development of Marine Fisheries," later nicknamed "The Blue Report," which restated the existence of the "Problem of the Commons" in marine fisheries, even if all the fishermen were of the same nationality.[5] This report concluded that the fishery management methods used at the time were aimed at guarding the interests of occupationally or geographically defined groups

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[1] Sigurdur Snævarr (1993), p. 182, and Sigfús Jónsson (1984) pp. 124–25.

[2] Sigfús Jónsson (1984) pp. 242–43.

[3] Fiskifélag Íslands, Útvegur 1992, p. 491.

[4] Actually, the report called for almost a 50% reduction of the cod catch, from roughly 400,000 metric tons to 230,000 metric tons in 1976. Halldór Jónsson (1990) p. 114.

[5] Icelanders had argued that competition among fishermen from different nations pursuing different goals with respect to the quantity and quality of fish brought ashore could lead to inefficient use of the resource. Foreigners would be concerned about balancing the cost and revenue for each given trip, whereas natives would take future catches into account in deciding what to fish and when to do it. Hence, the mood in Iceland had been: Get rid of foreigners from inside the 200 mile limit so that we can manage the resource in a responsible manner. Not until the "Blue Report" was published, had it been stated so forcefully that Icelandic boat owners could come to strike the "wrong" balance between their own present revenue and the future catches of all boat owners. The "Blue Report" made it clear that fishery management was necessary if fishery rent was to be created.

in Iceland, but had no roots in the biological sciences or economics. The heated debate that followed resulted in the establishment of a rudimentary effort restriction system. The effort restriction system banned trawlers, the most efficient vessels, from fishing cod during a specific number of days each year.[6] The investment in new vessels was to be conditional on the removal of older vessels from the fishing fleet.[7] This effort-controlling management system was in operation until 1984. In 1981 it was augmented by a Total Allowable Catch (TAC) target. The effort restriction experiment was negative on two counts: (1) The capacity of the fishing fleet continued to grow as fishing was still profitable and politicians could not resist pressure from would-be boat owners (figure 1 and table 1). Therefore, the overall cost of bringing a given TAC ashore was considered to be unnecessarily high. (2) It proved impossible to keep the actual catch in line with the TAC because the relation between effort and catch was not stable.[8]

After a short debate in 1983 from December 12th to the 28th, the Icelandic parliament empowered the Ministry of Fisheries to set the TAC inside the Icelandic fisheries' limits and to give an allotment to fishing vessels (Act 82/1983). In February 1984 the Ministry allotted a quota to each vessel according to a complicated set of rules. The catch history of the vessel during the period 1 November 1980 through 31 September 1983 was the basis for the vessel quota.[9]

In 1985 the catch quota system was extended for another year. The conditions that a vessel owner had to fulfill to be eligible for choosing effort restrictions (still augmented by a catch limit for cod), rather than catch restrictions, were eased. In 1986 the catch quota system was extended for two years. Some steps were taken to eliminate the effort quota. Again in 1988 the catch quota system was extended for another two years. The Icelandic parliament also augmented the first paragraph of the Fisheries Management Act to declare that the fish stocks in the waters around Iceland are the property of the Icelandic people. In 1990 a law was passed that made the catch quota system more permanent. The law eliminated the effort quota and extended the quota system to vessels between 6 and 10 tons, in addition to vessels 10 tons and over. At each turn, transferability of the catch quota was made easier.

The Role of Normative Fisheries Economics in Iceland

In the debate on how to manage the fisheries, Icelandic fisheries economists made the case for ITQs.[10] Arnason (1990) concludes that fisheries management systems suggested earlier in the literature call upon the fisheries manager to calculate the op-

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[6] Other vessels were also subject to this rule of codless days, but that regulation was less extensive.

[7] A governmental decree from the Ministry of the Fisheries, dated 14 July 1977 banned all vessels from catching cod inside the Icelandic Fisheries limit for a period of one week. Furthermore, all trawlers had to avoid cod for thirty days during the period of 14 July to 15 November of that year. Similar steps were taken during the period of the effort quota when the catch exceeded the target.

[8] Halldór Jónsson (1990), p. 116.

[9] Owners of vessels that were not in use during that period, or owners that had recently bought an old vessel and owners of vessels that had hired a new skipper since the end of the catch-history-period, could choose effort restrictions ("codless-days"). The decree allowed limited transferability of the allotted catch quotas, conditional on the agreement of the Ministry of Fisheries, the local chapter of the Fishermens' Union and the local authorities. (Government of Iceland: "Reglugerd um stjórn botnfiskveida 1984," Nr. 44/1984). The establishment of the catch quotas was regarded as a provisional decision to be revised within a year. The law and the decree were largely in line with the recommendations of The Fisheries Convention (Fiskithing), a body that counts both boat owners and fishermen as its members [Halldór Jónsson (1990) and Pálsson and Helgason (1995)].

[10] Arnason (1990), Pálsson and Helgason (1996), Helgason (1995), Halldór Jónsson (1990), and Sigurdur Snævarr (1993).

Table 1
Icelandic Fishing Vessel Fleet Size, Size of the Fishable Cod Stocks and Size of Icelandic Cod Catches, 1977–94.

Period	Change in Size of Fleet	Change in Size of Fishable Cod stock	Change in Size of Icelandic Catches
1977–1984, rudimentary "total" effort quota	+17%	–26%	–15%
1984–1990, rudimentary ITQs	+25%	–6.5%	+18%
1990–1994, revised ITQs	–3%	–29.5%	–35%

Sources: National Economic Institute and Marine Research Institute

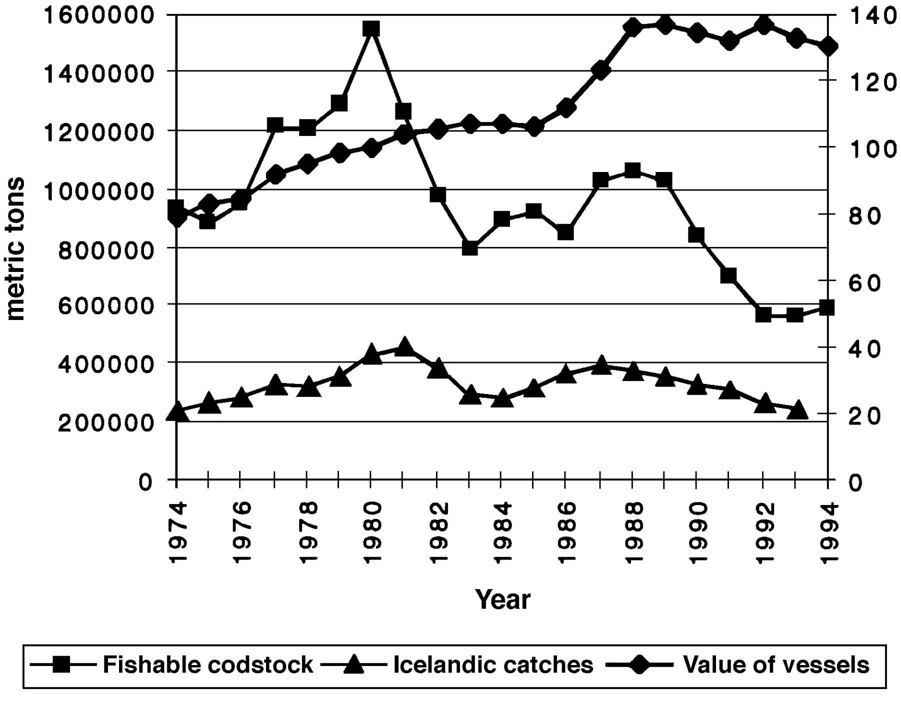

Figure 1. Value of Icelandic Fishing Fleet (right scale, 1980 = 100), Size of Icelandic Cod Stocks and Size of Catches of Icelandic Cod by Icelandic Vessels (left scale, metric tons)

timal level of taxes or subsidies in order to induce the right amount of fishing effort. He argues that the data required to perform these calculations are beyond the capacity of the manager to acquire. He subsequently states that a system of ITQs alleviates the information problem. Then, provided that a reasonably efficient quota market exists, the use of ITQs will also ensure that any total allowable catch will be harvested efficiently.

The discussion among fisheries economists influenced the Icelandic discourse on fisheries' management while the management system was under reconstruction.[11] The main conclusions from this normative fisheries economics literature rest upon several assumptions that are often implicitly made. First, it is usually assumed that it costs nothing to enforce the quota system. Fishery managers are assumed to be able to allot quotas and decide the yearly TAC without interference from boat owners, freezing plant owners, municipal councils, or other stakeholders. Second, it is usually assumed that fishing firms do not try to cheat and harvest more than the allotted quota of a given species. Therefore, the costly enforcement actions of the fisheries manager in reality are not modeled. It is shown in Matthiasson (1996a) that, if this assumption of cost-free enforcement is relaxed, some of the efficiency gain that the quota system yields may actually be an illusion as the cost of enforcement, and the benefits of control, accrue to different groups of people. Thirdly, fishing firms are explicitly supposed to be atomistic profit-maximizers without political leverage to gain subsidization of key inputs. This assumption has vast consequences for conclusions of the models. Some implications of having local community politicians using tax money to subsidize local firms on the quota market will be considered in a formal model later in this paper.[12]

Has Regulation Had a Substantial Effect on Fleet Size?

The need for fisheries management follows from the "tragedy of the commons" argument. The fishing fleet exceeds the productive capacity of the utilized fish stocks and fish stocks tend to be reduced to such an extent that fishing costs are unnecessarily high. Fisheries management must therefore have a significant effect on the biomass of fish and/or size of the fishing fleet.

Figure 1 shows the value of the Icelandic fishing fleet (in constant prices), the size of Icelandic cod stocks, and the size of the catches of Icelandic cod by Icelandic vessels. Judging from the normative literature one would expect the introduction of the various fishery management systems to induce an adjustment of the size of the fleet to the capacity of the fishing stocks. This has not happened. The value of the Icelandic vessels increased for most of the period from 1974 to 1994, with the exception of the last few years. In contrast the fishable stocks of cod reached the highest estimated value in 1980, and then a temporary low in 1983 followed by an all-time low in 1992. Icelandic cod catches show much less variability than do both the size of the fleet and the sizes of the fish stocks. According to the estimates of Icelandic economists, the fishing fleet was much bigger in 1980 than warranted by the carrying capacity of the fish stocks.[13] Consequently, it should be safe to conclude that the fleet size did not adjust to the carrying capacity of the fish stocks during the period under investigation.

Table 1 further documents the apparent inefficiency of the rudimentary management systems. The fishing fleet continued to grow throughout the first two periods at considerable speed and the Icelandic catches were obviously in excess of the capacity of the resource. In 1990–94 the growth of the fleet stopped, with catches ap-

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[11] Halldór Jónsson (1990), Neher, Arnason, and Mollett (1989), and Helgason (1995).

[12] Other authors have raised doubts about the conclusions of the normative literature on different grounds. Wilson, Acheson, Metcalfe, and Kleban (1994) state that the relation between fishing and size of the fish stocks is complex and probably chaotic. They state that ITQs are but one variation of what they call "numerical management schemes." The main weakness of such schemes is that they require an unreasonable amount of information.

[13] Thorvaldur Gylfason (1991, p. 41) quotes a statement made by Ragnar Arnason, where Arnason, in a paper from 1984, estimates the excess capacity in the Icelandic fishing fleet to be roughly 40%.

parently more in line with the growth potential of the stocks. This may have been due to a better management system. In all likelihood the persistent decline in the fishable cod stocks (the most valuable fish stocks) would eventually have triggered downsizing of the fleet. However, a successful fisheries management scheme should have induced a quicker and more extensive downsizing of the fleet.

In summary, the evidence from the data presented above indicates that the fisheries management systems adopted in Iceland did not alleviate the considerable excess capacity problem that existed. Furthermore, the cod stocks did not show signs of recovery until after 1994. The predictions of the performance of the new fishery management schemes were largely based on theoretical experiments. Experience from other fisheries management systems [see Townsend (1990)] indicates that theoretically-based predictions of the performance of such systems may be inexact.

Local Municipalities as Stakeholders in Fishing Firms

It is common in many countries for municipalities to operate their utilities as not-for-profit organizations. In Iceland, local authorities organize the distribution of electricity and geothermal water, the operation of harbors, *etc*., in this manner. Non-profit operations are also of significance in the case of municipal engagement in the fisheries, which could possibly account for the discrepancy between expected and observed behavior of fishing firms with respect to capacity reduction.[14] In Iceland municipal ownership or partial ownership of fishing firms has historically been, and still is, important. Occasionally, municipalities have operated fishing firms as not-for-profit enterprises, although the organizational form of the limited liability company is also in use.[15]

The municipalities have often stepped in when other investors have not been willing to risk their money in the operation of the firm. The dismantling of a local firm could imply that its productive assets would be located in a different municipality. An integrated fishing firm is often the backbone of economic activity in a given coastal community.[16] The municipality loses tax income in the wake of fishing firm downsizing and relocation. The municipalities may, in their short-run calculations of the returns for “saving” a fishing firm from being relocated, come to conclusions that differ from those that would be reached by a private investor. The local council should be expected to have a broader set of goals than profit-maximization when they decide if and how to become involved in the management of a fishing firm. The local council should be expected to regard their assets in a fishing firm on a par with assets in a hospital, a school, or a public transportation utility. Not only

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[14] A profit maximizing firm buying and selling inputs and outputs in atomistic markets will in the long-run have to operate at the bottom of its average cost curve. A not-for-profit firm will not be forced to economize with inputs in this manner. Specificially, such a firm will not be forced to economize use of capital equipment or marketable catch quotas to the same extent as a profit-maximizing firm would do. Hence, a fishing vessel fleet operated partly by not-for-profit firms and a fishing fleet only operated by profit-maximizing firms may react differently to various fishery management schemes. For elaboration see Matthiasson (1996b).

[15] Local municipal ownership of shares in local fishing firms may be of different historical origin in each case. The municipal council may have been one of the founders, or even the only founder, of a fishing firm. The municipal council may have acquired stock in the fishing firm as a result of financial restructuring, either in exchange for writing off debt or in exchange for cash. Hence, for a variety of reasons, local municipalities may hold the majority or a large minority of shares in fishing firms located in the community. Local municipalities may step in and buy shares in firms that otherwise might be moved out of the municipality. And local municipalities may sell shares they have acquired in the past at below market price on the condition that the assets of the firm are kept inside the boundaries of the municipality.

[16] Eythórsson (1996), pp. 278–79.

Table 2
Ownership of Icelandic Trawlers, 1945–70.

Year	Total Number of Icelandic Trawlers	Number of Trawlers Owned and Operated by Private Firms	Number of Trawlers Owned and Operated by Central or Local Governments, or by Firms Where Local Governments Hold Majority
1945	29	27	2
1947	32	24	8
1950	35	18	17
1960	45	20	25
1970	22	10	12

Source: Thorleifur Óskarsson (1991), pp. 252–54.

do the municipalities have a broader set of goals than would a private investor, but they also command a broader set of financial instruments than would a private investor. Local municipal authorities can, for instance, put future tax revenue up as collateral for loans, an action extensively used by Icelandic municipal councils, as documented in table 3.

The extent of municipal ownership of shares in fishing firms is not available,[17] but the municipalities were a big player in the renewal of the capital intensive part of the fishing fleet after World War II (table 2).

Most of the trawlers operated in the 1950s and 1960s were built after World War II. Many of the local governments that had a stake in fishing organized their operation as a public utility. Others organized the operation in the form of a private company.

Due to the changed economic conditions, hardly any new investment was made in trawlers during the 1960s. But in the 1970s, the government offered generous loans to facilitate investment in new trawlers. In the period of a few years 100 new big stern trawlers were bought to operate in Icelandic waters.[18] Unfortunately, no comprehensive study similar to the one reported in table 2 exists, but a quick estimate shows that municipally controlled companies acquired one-third to one-quarter of the new stern trawlers.

All the utility-organized municipal fishing firms have been reorganized as limited liability companies, but the local authorities still hold a big stake in the transformed companies. The reasons for the reorganization are many, and include a general drive for privatization of public firms, and the need for financial and organizational restructuring of the Icelandic fishing industry in response to the scarcity of fish in the early 1980s.

In 1993 the Federation of Icelandic Municipalities (Samband íslenskra sveitarfélaga) conducted a survey among its members regarding new financial commitments granted to businesses. Table 3 shows how these commitments have evolved during the period 1987–91.

In the first two years, aid was mostly in the form of loan guarantees. In more recent years the municipalities extended their involvement in fishing firms by in-

[17] Arnason (1995) estimates that 5% of total shares are in the hands of municipalities. Eythórsson (1996) states that in the early 1980s, 10% to 20% of the industry was under municipal ownership. These figures underestimate the responsibility of the local authorities. In communities where an integrated fishing firm is the major source of jobs, the municipal council may have to choose between guaranteeing a loan to the fishing firm or relocation of the fishing activity.
[18] Sigfús Jónsson (1991), pp. 146–47.

Table 3
New Financial Commitments by Municipalities to Fishing and Fish Processing Firms, 1987 to 1991 (millions of 1991 krónur).

Type of Commitment by the Municipalities	1987	1988	1989	1990	1991
New equity holdings	52.0	32.4	219.9	416.8	359.4
New loans to fishing firms	10.6	23.5	24.9	3.7	59.1
Tax write-offs	3.3	0.4	7.0	6.2	4.8
Direct subsidies	1.8	2.3	0.1	0.1	1.9
Loan guarantees	119.6	224.1	476.2	151.0	262.9
Total	187.3	282.7	728.1	577.8	688.1
To all industries	516.4	523.0	913.4	865.9	929.9
Fishing industry share	36.27%	54.05%	79.71%	66.73%	74.00%

Source: Federation of Icelandic Municipalities.

creasing their equity holdings. That this change coincided with the introduction of a more thorough implementation of the ITQ system may be pure coincidence. But local governments are increasing their involvement in the fisheries, and the fishing industry has increased its total share of municipal aid from slightly more than 36% in 1989 to 65% to 75% in later years.

Municipal help to fishing firms can also be significant in per capita terms (figure 2). The figures for gross capital transfers should be compared to the per capita income from municipal taxes, which were ISK 100,000 in 1992. Per capita municipal expenditure on health and welfare was approximately ISK 5,000 that year, ISK 25,000 on education, and ISK 20,000 on road construction. Hence, it may be concluded that money transfers by municipalities to and from fisheries firms are of considerable size and importance for some small municipalities, though these transfers are more modest in size in the aggregate (appendix 1).

Management and Fleet Size

The Icelandic fishing fleet has contracted slowly in the wake of the introduction of stiff management schemes. Other researchers have also observed a slow response to ITQ regulated fisheries. This result can be attributed to a variety of factors. The value of waiting is an explanation suggested by Just and Weninger (1997). According to them, the delayed exit of fishermen from the Mid-Atlantic surf clam and ocean quahog fisheries occurs because of the existence of uncertainty and the low opportunity cost of keeping a vessel and the right associated with it. Brod and Shobe (1996) observe that Atlantic wreckfish fishers off the east coast of the USA hold onto allotted fishing rights even if they do not exercise them during a season, and even if potential buyers are present in the market. Brod and Shobe argue that fishermen or boat owners hold fishing rights as a form of job insurance.

In Iceland, a number of municipal councils either own shares in a fishing firm or they have supplied collateral for substantial loans to fishing firms (table 3), motivated usually by job creation or job preservation considerations.

There may be a link between the response of fishing firms to the fishery management schemes and municipal responsibility. To be more concrete one might ask: How will it affect the working of the ITQ system if municipal councils subsidize

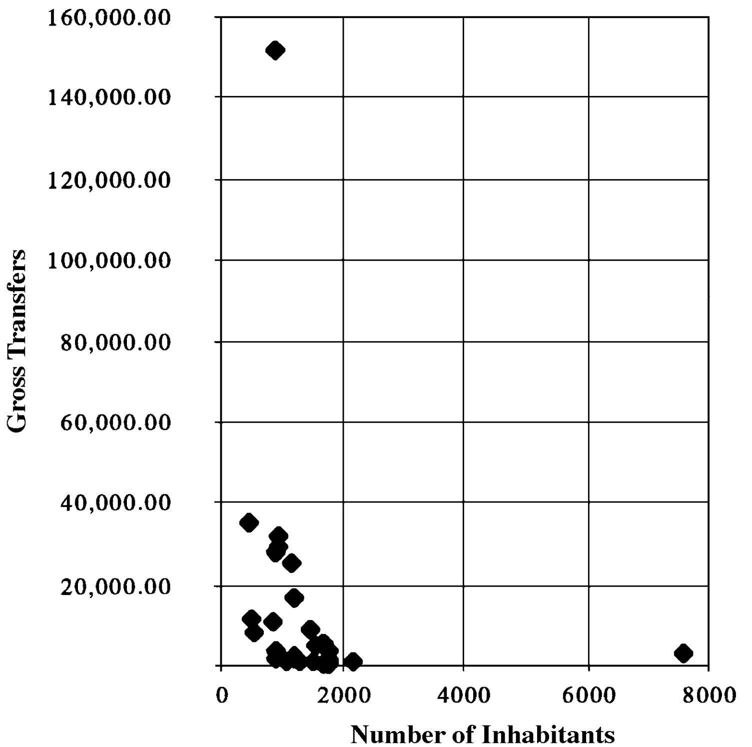

Figure 2. Per Capita Municipal Investment in Fishery Firms and Gross Capital Transfers from Fishing Firms According to the Size of Municipality, 1991–93 (source: see appendix 1).

low-efficiency fishing firms to insure that those firms acquire sufficient quotas to keep their operation minimally affected by the ITQ system? In the following sections of this paper a theoretical model is developed to answer this question.

The Model

The discussion will be conducted in several stages. First, the free access situation will be considered. Under free access, all would-be vessel owners are allowed to test their ability and operate a vessel. Equilibrium in the industry is reached when there are no would-be vessel owners capable of earning positive rents outside of the industry. The next step is to consider the socially optimal solution. The need to do so arises from the externality that arises because of the fact that tomorrow's catch hinges on today's conservation. The third step is to consider whether ITQs solve the social planners' problem. A fourth step is to consider the working of an ITQ system where low-efficiency vessels receive a subsidy to buy quotas.

The Free Access System

The model employed is a modified version of the model by Grafton (1992). I will indicate where my version differs from Grafton's version. The Grafton paper can be consulted for justification of simplifications and assumptions.

Assume that a fishing fleet consists of a number of vessels of different productivity.[19] Productivity differences between equally equipped vessels have been observed in many fisheries around the world, [see Acherson (1981) for a review]. Rank vessels such that the most efficient vessels acquire the lowest index. Assume further that the cost function for vessel i can be written as:

$$C_i = \frac{i(i-1)c}{2b^2} q_i^2 + rK, \quad i = 2, \ldots, N+1 \tag{1}$$

Here C_i is the cost of operating vessel i for one year, assuming that total catch during the year is q_i and that the size of the fish stock utilized is b. K stands for fixed costs associated with starting a fishing firm. These costs must be covered as the analysis is long-term, deterministic, and steady state. Hence, investors will only risk their money on a project if they are sure of both covering fixed costs and earning interest on the initial investment during the lifetime of the vessel. The market rate of interest is r, and c is a constant.[20] The cost will increase in quadratic terms with the catch, *ceteris paribus*. The productivity difference between vessels is such that it will be three times more expensive for the second most efficient vessel to catch a given amount of fish than for the most efficient one. This productivity difference between vessels decreases as less effective vessels are compared.[21] Hence, the costs of bringing a given catch ashore would be 20% higher for the eleventh most effective, than for the tenth most effective vessel. This relative cost distance has fallen to 2% for the hundred-first and the hundredth most efficient vessels.

The cost function represented above can be viewed as a generalization of the cost function represented in Grafton (1992). For simplicity it will be assumed that the fixed cost, K, is equal across vessels.[22] This cost element is tied to various expenses such as the vessel owner's legal expenses related to getting the vessel into operation, expenses accruing due to the process of learning about rules and regulations that must be obeyed, *etc*. Relaxing the assumption of uniform K across vessels would complicate matters without adding much new insight.

Now, the profit from operation of vessel i can be written as:

$$\Pi_i = p_i q_i - C_i \quad i = 2, \ldots, N+1 \tag{2}$$

The first-order condition from profit-maximization is that:

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[19] This assumption differs from assumption 2 in Arnason (1990). Arnason assumes that all fishing firms are alike. For extension of the Arnason paper covering the more realistic heterogeneous case, consult Heaps (1993). Heaps shows that Arnason's conclusions may hinge on the homogeneity assumption.

[20] The parameter c can be interpreted as being the (exogenous) unit cost of effort. Assume free competition on all input- and output-markets. By duality theory $q_i = b\sqrt{2e/i(i-1)}$. Here e is fishing effort. Fishing effort is produced by use of oil, gear, labor, vessel capacity, *etc*. Insert this last result in equation (1) to yield: $C_i = ce + rK$. Hence, c can be interpreted as cost of fishery effort. See also Grafton (1992). Exogenous unit cost of effort is widely employed in fisheries economics [*e.g.*, Clark, Clark, and Munro (1979); and Conrad and Clark (1987)]. For critical discussion of production and cost functions as used in the fishery literature, see Doll (1988).

[21] Acherson (1981) cites Wadel (1972) to the effect that in Newfoundland one purse seiner may catch as much as five or ten less productive ones. Acherson cites another source, claiming that in one place 15% of the fishermen harvested 50% of the landings. For discussion regarding productivity differences between skippers in Iceland, see Pálsson (1987), Durrenberger and Palsson (1986), Thorlindsson (1988), and Thorlindsson (1994).

[22] Grafton models a fleet consisting of two efficiency categories of vessels. Fixed costs can vary. In this sense, the present model is more limited than the Grafton model.

$$p - \frac{cq_i(i)(i-1)}{b^2} = 0 \tag{3}$$

The second-order condition for profit maximum is satisfied.

As production units differ in terms of productivity, intramarginal rents will be earned on the more efficient vessels. An owner of production skills will consider entering the industry if rents to be earned are nonnegative. For the last vessel, the decision of the owner of production skills will be invariant as to whether to put his resources to work in the fishing industry or in other industries. Hence,

$$\Pi_{N+1} = q_{N+1}\left[p - \frac{cq_{N+1}(N)(N+1)}{2b^2}\right] - rK = 0 \tag{4}$$

Assume, as does Grafton (1992), that there is a parabolic relationship between a steady state harvest and the fish stock biomass:

$$\sum_{i=2}^{N+1} q_i = Bb(\bar{b} - b) \tag{5}$$

Here, b is the biomass of the fish stock, $\bar{b}$ is the maximum biomass and B is a constant.

Utilizing equation (3) yields:

$$\sum_{i=2}^{N+1} q_i = \sum_{i=2}^{N+1} \frac{pb^2}{c(i)(i-1)} = \frac{pb^2}{c} \sum_{i=2}^{N+1} \frac{1}{(i)(i-1)} = \frac{pb^2}{c}\left(1 - \frac{1}{N+1}\right) \tag{6}$$

In deriving equation (6) it is utilized that

$$\sum_{s=2}^{n} \frac{1}{s(s-1)} = 1 - \frac{1}{n}.$$

For proof, consult Sydsaeter and Hammond (1995, p. 852).

Combining equations (5) and (6), assuming that $N \approx N+1$ and rearranging yields:

$$b_{fa} = \bar{b}\,\frac{B}{p/c + B} \tag{7}$$

Hence, the steady state free-access-biomass (b_{fa}) will decrease with the price of the landed catch, p and increase as variable costs (represented by c) increase. Note also that the steady state biomass will increase as the constants B and $\bar{b}$ increase. Furthermore, from equation (5) we know that the maximum sustainable yield (MSY) is harvested if the stock is kept at the level $\frac{1}{2}\bar{b}$. From equation (7) we see that the free access situation will induce maximal harvest from the resource in the instance when $p/c = B$.

Now, combining equations (3), (4), and (5), ignoring integer problems, yields:

$$N \cong \frac{p\bar{b}B}{(p/c + B)\sqrt{2crK}} \tag{8}$$

Hence, it may be deduced from equation (8) that the number of vessels practicing steady state harvesting will increase with an increased p, and fall with an increase in the market rate of interest, r. The number of vessels will also be reduced when fixed costs are increased.

The above results can be explained by the fact that when the price of the landed catch increases, more vessels will be put in the water at the same time as each existing vessel owner tries to expand his operation. But the growth potential of the fish stocks is unaffected by the increase in price. Hence, equilibrium in the industry will not be restored until the fish stocks have been reduced so that the costs faced by each vessel are inflated and catch per vessel reduced. Utilizing equations (3) and (7) it may be shown that catch per vessel will either increase or decrease in the wake of a price change:

$$\frac{\partial q_i}{\partial (p/c)} \frac{p/c}{q_i} = \frac{B - p/c}{B + p/c} \tag{9}$$

Hence, if $B > p/c$, then catch per vessel will increase, but decrease if $B < p/c$. The reason for this ambiguity is that when $B > p/c$, the biostock is bigger than the maximum sustainable yield biostock, $\frac{1}{2}\bar{b}$. Hence, if the situation is such as described, total harvest can be increased by diminishing the stock. Consequently, the stock can sustain both a higher number of vessels and an increased catch per vessel. In the case that $B < p/c$, the situation is reversed.

Solution of the Social Planners' Problem

The problem of the social planner is to maximize the (annualized) long-term rents from the fishing industry, taking into account the biological facts. Successful management of the resource may change the market for the product[23] and hence influence the product price. Successful management may also affect the unit price of effort.[24] It will be assumed in the remainder of the paper that product and input prices are uninfluenced by the conduct of the fisheries manager or the fishery management scheme chosen.

The objective of the fisheries manager can be written as follows:

$$\max_{q_2,\ldots,q_{S+1},S,b} \sum_{i=2}^{S+1} \left[pq_i - \frac{cq_i^2(i)(i-1)}{2b^2} \right] - SrK \quad \text{s.t.} \sum_{i=2}^{S+1} q_i = Bb(\bar{b} - b) \tag{10}$$

Here, S is the number of vessels associated with a socially optimal fishery.

The first-order conditions for the solution of this problem are given by equations (11) to (15). First, catch capacity of each vessel should be utilized so as:

$$p - \frac{cq_i(i)(i-1)}{b^2} - \lambda = 0, \quad i = 2, \ldots, S+1 \tag{11}$$

Here λ is the Lagrange multiplier associated with the resource constraint in equation (10). This multiplier can be interpreted as the shadow value of the resource.

Secondly, the biomass should be kept at such a level that the following condition is fulfilled:

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[23] For examples of this see Matulich, Mittelhammer, and Reberte (1996) footnote 4.

[24] An example of this effect on costs occurs if demand for some special factors decreases. If these factors are in fixed supply and if they have few alternative uses, their price might be reduced, thus reducing unit cost of effort.

$$\sum_{i=2}^{S+1} \frac{cq_i^2(i)(i-1)}{b^3} + \lambda B(\bar{b} - 2b) = 0 \tag{12}$$

For the "last" vessel that enters the industry the following equation should hold:

$$pq_{S+1} - \frac{cq_{S+1}^2(S+1)(S)}{2b^2} - rK - \lambda q_{S+1} = 0 \tag{13}$$

Lastly, if the growth potential of the stock is not fully utilized, then the shadow value of the resource should be set to zero:

$$\left[\sum_{i=2}^{S+1} q_i - Bb(\bar{b} - b)\right]\lambda = 0 \tag{14}$$

The system (11) to (14) consists of $S + 3$ equations that determine the endogenous variables $q_2, \ldots, q_{S+1}$, S, b, and λ. The exogenous variables are p, c, B, and $\bar{b}$. After some terse algebra [using equation (11) to isolate q_i inserting that result in equations (12) and (14) and combining the two to isolate b] we can conclude that:

$$b_{so} = \bar{b}\,\frac{B + p/c}{B + 2\,p/c} \tag{15}$$

Here the subscript *so* indicates that it is the socially optimal size of the biomass which is under consideration. Hence, the bigger B *is*, the bigger the optimal biomass is. Or in other words, a fast growing fish stock should be kept large. Note also that the higher the on-shore price p is relative to the effort-unit price c, the closer is the optimal biostock to being 50% of the potential biostock. We will further find that:

$$\lambda = \frac{p^2/c}{B + p/c} \tag{16}$$

Dividing equation (16) by p on both sides yields:

$$\frac{\lambda}{p} = \frac{p/c}{B + p/c} < 1 \tag{17}$$

Hence, the shadow value of the resource is always less than the price of catch. Note also that the shadow value is lower as a percentage of the on-shore price, the faster the growth of the stock (the bigger is B in other words). Finally we have:

$$S = \frac{pB\bar{b}}{(B + 2p/c)\sqrt{2crK}} \tag{18}$$

It is straightforward to establish from equations (7) and (15) that:

$$b_{so} > b_{fa} \tag{19}$$

It is also straightforward to establish from equations (8) and (17) that:

$$\frac{N}{S} = \frac{B + 2p/c}{B + p/c} > 1 \tag{20}$$

Hence, $N > S$, so that the free access solution is established with more vessels than is socially optimal, while equation (19) shows that under free access the biostock is suboptimal.

The discussion above demonstrates that the predictions of the model are much in line with conventional wisdom in this field, as is to be expected.

Implementing the Optimal Solution

If we ignore the problem of transferring the system from one steady state to another, then at first glance a simple solution of the social planners' problem would seem to be to collect a landing tax of $(p^2/c)/(p/c + B)$ for every kilo of catch brought ashore. Each vessel owner should then operate his vessel at the socially correct level and the number of vessels should be socially optimal. This solution would require that the fishery manager estimate B, c, and p. Such estimation may be a complicated matter. Note that the problem of "race for fish" or "Derby-fishing" emphasized by Dupont (1991) would not arise in the context of the present model as it would be uneconomical for each vessel owner to expand his catch beyond the socially optimal catch for his vessel.[25]

Other forms of regulation have also been proposed based on the fact that B may be hard to measure, and even hard to define and still harder to update. In practical settings the fishery manager would be required to announce the magnitude of the landing tax some period into the future. The periodic and erratic nature of fisheries would make such a task very hard and even impossible.

Landed catch is easily measured and defined and has been measured through the years for purposes other than those tied to fishery management; hence, the idea of basing regulation on catch quotas rather than, or supplemental to, landing taxes.[26] In a homogenous fleet the problem of the fishery manager might be solved by allocating catch quotas of equal size to each vessel, observing the assumed carrying capacity of the fish stock. In heterogenous fleets, like the one that is analyzed in the present paper, the establishment of the socially "correct" quota distribution is a more demanding task. One approach is to distribute nontransferable fishing rights for free, based on the catch history of each vessel or each skipper. Such handing out of rights can result in suboptimal distribution of rights. In order to correct misallocations, the suggestion is to make fishing rights transferable and marketable. Hopefully, under such a system misallocations of quotas would be corrected on the quota market.

The income accruing to a vessel operating under a quota regime with individual transferable quota rights when those rights are distributed for free comes from two sources. One source is the profit from operating the vessel, the other source is the

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[25] This might require that TACs be set for very short seasons at each time. Hence, the problem of Derby-fishing might surface in a more realistic version of the present model.

[26] Ideally, the information needed for calculating a "correct" level of a Total Allowable Catch (TAC) is no less than the information needed for calculating the optimal level of a landing tax. But fishery management schemes are usually established as a result of overfishing. Hence, most of the stakeholders in the fishery accept a need to restrict the catch. The link between catch restriction and announced TAC is clear and obvious. The link between a landing tax and restriction of catch may be less obvious. Hence, it may be easier to gain acceptance for a TAC among fishers than for a landing tax.

(imputed) rental value of the quota initially awarded. Hence, the income accruing may be written as:

$$\Pi_i + \Gamma A_i = pq_i - C_i - \Gamma\alpha_i \tag{21}$$

Here Γ is market (rental-) price of the quota, A_i is initial allocation of the quota, while α_i is the quota bought or rented. If the quota is rented out, then $\alpha_i < 0$ and $-\Gamma\alpha_i > 0$, representing an additional source of profit. When the right to fish is rented from someone else, $\alpha_i > 0$, and $-\Gamma\alpha_i < 0$ and thus a cost, as discussed. Each vessel has to observe the requirement that the catch is not in excess of the quota allocated and/or rented:

$$q_i \leq A_i + \alpha_i \tag{22}$$

A requirement that agents make use of all productive assets ensures that equation (22) is fulfilled with equality.

The first-order condition of profit-maximization can be written as:

$$p - \frac{cq_i(i)(i-1)}{b^2} - \Gamma = 0, \quad i = 2, \ldots, J+1 \tag{23}$$

Rearranging equation (23) and summing over all i, ignoring the serious problem of discarding by assuming that total allowable catch (TAC) equals actual catch, $\sum_i q_i = \sum_i (A_i + \alpha_i) = \text{TAC}$, yields:

$$\Gamma = p - \frac{TAC \cdot c}{b^2}\frac{J+1}{J} \cong p - \frac{TAC \cdot c}{b^2} \tag{24}$$

Now assume that $\text{TAC} = \sum_{i=2}^{J+1} q_i$ and that the size of the fish stock equals the socially optimal size of the fish stock so that $b = b_{so}$ given by equation (15), then we can establish that:

$$\Gamma = \frac{p^2}{Bc + p} = \lambda \tag{25}$$

Hence, the quota price and the shadow price of the resource coincide according to the socially optimal solution. Consequently, the ITQ system will yield the socially optimal solution as long as the system is correctly described by equations (23) through (25). Hence, it may be concluded that:

$$S = J \tag{26}$$

Thus, the number of vessels under ITQs is equal to the socially optimal number of vessels.

Robustness of the Solution

The transition from free access to the optimal solution will require some reduction of the fleet. Hence, it may be that implementation of an ITQ regime will induce some vessel owners to take their vessels out of operation. Such an act may have consequences in the local community where this happens. For instance, the local processing sector may experience a drop in supply of fresh fish.[27] Consider now the situation where the politicians in the municipalities of the L–M least effective vessels subsidize the fishing firms by paying part of the quota price out of municipal funds.[28] Denote the subsidization rate as γ. Such subsidization will affect the equilibrium rental price of the quota on the market. Assume that $M \approx M + 1$. Further assume that total catch is given as:

$$\sum_{i=2}^{M+1} q_i + \sum_{j=M+2}^{L+M+1} q_j = TAC \tag{27}$$

Now, q_i is given by equation (23). Subsidized firms are faced with the quota price $(1 - \gamma)\Gamma$. Consequently, a subsidized firm supply of catch, q_j is not given by equation (23) but by:

$$q_j = \frac{\left(P - [1 - \gamma]\Gamma\right)b^2}{j(j - 1)} \tag{28}$$

Hence, utilizing equations (23), (27), and (28), the equilibrium rental price of a quota can be written as:

$$\Gamma_{lc} = \frac{(L + M + 1)(M + 2) + L - 1}{(L + M + 1)(M + 2) + (L - 1)(1 - \gamma)}\, p - \frac{(L + M + 1)(M + 2)}{(L + M + 1)(M + 2) + (L - 1)(1 - \gamma)}\, \frac{TAC \cdot c}{b^2} \tag{29}$$

Here the subscript lc indicates that the quota lease price is influenced by local communities subsidizing the low-efficiency vessels. It may be checked that if $L = 0$, then equations (29) and (24) yield (almost) identical results. Now, for L, $\gamma > 0$ the term which accompanies p on the right-hand-side of equation (29)

$$\frac{(L + M + 1)(M + 2) + L - 1}{(L + M + 1)(M + 2) + (L - 1)(1 - \gamma)} > 1$$

Furthermore, we have that the term accompanying TAC*c/b^2:

$$\frac{(L + M + 1)(M + 2)}{(L + M + 1)(M + 2) + (L - 1)(1 - \gamma)} < 1$$

Hence, it may be concluded that:

$$\Gamma_{lc} > \lambda \tag{30}$$

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[27] For a detailed analysis of how fishery management affects the processing sector, consult Matulich, Mittelhammer, and Reberte (1996).

[28] There are many ways how this might be done. For example, one way is that the municipality rented and rerented the quota to the low efficiency firm at a reduced price. Or the municipality could supply municipal services at a reduced price as long as the firm brought its catch to shore in that municipality, *etc*.

Consequently, the quota system solution and the social planner solution will no longer coincide. The high-efficiency and nonsubsidized vessels will be underutilized as compared to the socially optimal solution, while the subsidized and low-efficiency vessels will fish more than is optimal. Furthermore, the number of vessels will be higher than in the socially optimal solution. As local politicians subsidize local firms in the quota market, demand for quotas is increased and the price of a quota increases, as quotas are in restricted supply. The nonsubsidized vessels will face higher costs than they would have had the subsidization not taken place. Hence, the nonsubsidized vessels will restrict their operation as compared with the optimal solution.

When Will ITQs be Successful?

The ITQ system may replicate the socially optimal solution if left alone and implemented according to the book.[29] But when the fishery manager and managers at other levels of government have conflicting goals, the ITQ system may produce socially suboptimal solutions. Remember that the municipal politicians are playing a very serious game against each other. All of them will believe, rightly or wrongly, that the future of their community hinges on the quota holdings of fishing firms in their community. They will know that the firm that loses its quota will shut down its operation, presumably adding people to the list of unemployed. Hence, they will find themselves forced to participate in the race for keeping quotas in their communities.

It is to be expected that ITQ systems implemented in unimportant fisheries fare better than ITQ systems implemented in important fisheries because local politicians are unlikely to pay attention to a regulated fishery that employs relatively few people.

We can also expect that ITQ systems implemented in centralized fisheries are successful. If all fishers and vessels come from only one municipality, fishing interests are less likely to get the politicians involved in a quota-grab race than when the industry is dispersed among several municipalities.

Some fisheries are based on migrating stocks that change their pattern of migration from time to time, like capelin and the once large and variable Atlanto-Scandic herring stock. Which harbors are favored by the skippers and the owners of the vessels depends on the behavior of the stock at each time. Hence, having a stake in these fisheries is less likely to produce results in terms of local employment than would a stake in more stable fisheries. Thus, local politicians are likely to emphasize demersal fisheries, rather than pelagic fisheries, at least initially.

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[29] It is important to note that the ITQ system, even when implemented by the book, can produce socially suboptimal results. The socially optimal solution is derived on the condition that social costs and benefits are measured by individual willingness-to-pay and by opportunity costs, thus incorporating all secondary costs and benefits. It is well established that market prices will not reflect opportunity costs in the face of public goods and externalities.

Furthermore, implementation of a fishery management system can be viewed as a public project. Evaluation of public projects is based on a social choice rule, implicitly or explicitly given. Hence, a proposition regarding the relation between the ITQ system and the socially optimal solution must hinge on the social welfare function applied by the decision maker. Assume that the problem of public goods and externalities could be ignored. Then the proposition that the ITQ system without lump sum transfers of wealth from gainers replicating the socially optimal solution would require that all individuals had equal weight in the social welfare function underlying the social choice rule. Furthermore, the social choice rule would have to be such that the Kaldor potential Pareto compensation principle applied (so that benefits were positive if gainers could potentially, rather than actually, compensate the losers).

Conclusions

Since 1974 the catch capacity of the Icelandic fishing fleet has been thought to be in excess of the carrying capacity of the Icelandic fishing stocks. Various fisheries management schemes have been attempted in order to reduce the excess capacity of the fleet. The adjustment in the size of the fleet has been slow compared to the hopes of advocates of fishery management. The model presented in this paper suggests that the considerable involvement of local authorities in the operation of the Icelandic fishing fleet may be one of the factors responsible for the slow adjustment.

One of the goals of fishery management is to enhance efficiency in production. Many economists suggest the use of a quota-allotment system to reach that goal. Most economists acknowledge that different allotment systems have different distributional consequences. Montgomery (1972) showed that the initial distribution of pollution rights does not affect the efficiency of pollution license programs while initial allocation is equivalent to a lump sum subsidy. The Arnason (1990) paper can be viewed as a restatement of this result for the fisheries case [for political conclusions based on the Arnason (1990) paper, consult Arnason and Runolfsson (1991)].

The lesson of the model developed in the present paper is that the method of allotment may matter when firms have the political leverage to influence their profitability conditions as a consequence of the new fishery management system. We can conclude that the political leverage of fishing firms is higher when ITQs are initially given away for free than when ITQs are auctioned off. When ITQs are allotted for free, the cost for a local municipal politician of subsidizing a firm that rents its quota is $\gamma\Gamma_{lc}\alpha_i = \gamma\Gamma_{lc}[q_i - A_i]$. Now, if the ITQ were auctioned, but not handed out, then the cost would be $\gamma\Gamma_{lc}q_i > \gamma\Gamma_{lc}\alpha_i$, since the full quota rent must be paid. Hence, the local municipality politician would find it much more expensive to keep up a given catch ensuring policy when ITQs are auctioned than when they are handed out initially for free.

Hence, one of possibly many reasons that the Icelandic fishing fleet has been slow in contracting in the wake of ITQ management may be that the least effective fishing firms have been able to counteract the profitability consequences of the introduced management system. This may not have been foreseen when the management system was initiated.

References

Acherson, J.M. 1981. Anthropology of Fishing. *Annual Review Anthropology* 10:275–316.

Arnason, R. 1990. Minimum Information Management in Fisheries. *Canadian Journal of Economics* (3):630–53.

___. 1995. *The Icelandic Fisheries. Evolution and Management of a Fishing Industry.* Fishing News Books.

Arnason, R., and B.T. Runolfsson. 1991. *Er Kvótakerfid Hagkvæmt?* [*Is the Quota System Efficient?*] Reykjavík: Stofnun Jons Thorlakssonar.

Brod, A., and W. Shobe. 1996. The Demand for ITQs: The Puzzle of the Atlantic Wreckfish Industry. Department of Economics, University of North Carolina at Greensboro.

Clark, C.W., F.H. Clark, and G. Munro. 1979. The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment. *Econometrica* 13(1):25–47.

Conrad, J.M., and C.W. Clark. 1987. *Natural Resource Economics*. New York: Cambridge University Press.

Copes, P. 1986. A Critical Review of the Individual Quota as a Device in Fisheries Management. *Land Economics* 62(3):278–91.

___. 1992. Individual Fishing Rights: Some Implications of Transferability. Simon Fraser University, Institute of Fisheries Analysis. Discussion Paper 92-1.
Doll, J.P. 1988. Traditional Economic Models of Fishing Vessels: A Review with Discussion. *Marine Resource Economics* 5(2):99–123.
Dupont, D.P. 1991. Fishing Vessel Quotas, Royalty Taxes, and the Structure of a Fishing Industry. Department of Economics Brock University, St. Catharines, Canada.
___. 1993. Price Uncertainty, Expectations Formation and Fishers' Location Choices. *Marine Resource Economics* 8:219–47.
Durrenberger, P., and Pálsson, G. 1986. Finding Fish: The Tactics of Icelandic Skippers. *American Ethnologist* 13(2):213–29.
Eythórsson, E. 1996. Theory and Prices of ITQs in Iceland. *Marine Policy* 20(3):269–81.
Grafton, R.Q. 1991. Rent Capture in an Individual Transferable Quota Fishery. *Canadian Journal of Fisheries and Aquatic Science* 49:497–503.
Gylfason, T. 1991. *Hagfrædi, Stjórnmál og Menning* [*Economics, Politics and Culture*]. Reykjavík: Hid íslenska Bókmenntafélag.
Hannesson, R. 1978. *Economics of Fisheries.* Oslo: Universitetsforlaget.
Heaps, T. 1993. A Note on Minimum Information Management in Fisheries. Institute of Fisheries Analysis, Simon Fraser University.
Helgason, A. 1995. The Lords of the Sea and the Morality of Exchange. M.A. Thesis, University of Iceland, Faculty of Social Science.
Jónsson, H. 1990. *Ákvardanataka í sjávarútvegi og stjórnun fiskveida* [*Decision Making and Fishery Management*]. Samfélagstídindi 10(1):99–141.
Jónsson, S. 1984 Sjávarútvegur Íslendinga á tuttugustu öld. [Development of Icelandic Fisheries in the 20th Century]. Reykjavík: Hid íslenska bókmenntafélag.
Just, R.E., and Q. Weninger. 1997. An Analysis of Transition from Limited Entry to Transferable Quota: Non-Marshallian Principles for Fisheries Management. *Natural Resource Modelling.* Forthcoming.
Matthiasson, T. 1992. Principles for Distribution of Rent from a "Commons." *Marine Policy* 16(3):210–31.
___. 1996a. Why Fishing Fleets Tend to be "Too Big." *Marine Resource Economics* 11(3):173–79.
___. 1996b. Local Governments in the Icelandic ITQ Market. Will They Sell? Institute of Economic Studies Working Paper, University of Iceland.
Matulich, S.C., R.C. Mittelhammer, and C. Reberte. 1996. Toward a More Complete Model of Individual Transferable Fishing Quotas: Implications of Incorporating the Processing Sector. *Journal of Environmental Economics and Management* 31(1):112–28.
Montgomery, W. 1972. Markets in Licenses and Efficient Pollution Control Programs. *Journal of Economic Theory* 5(3):395–418.
Neher, P.A., R. Arnason, and N. Mollett, eds. 1989. *Rights Based Fishing.* Vol. 169. NATO ASI series, Series E: Applied Sciences. Netherlands: Kluwer Academic Publishers.
Óskarsson, T. 1991. *Íslensk Togaraútgerd 1945–1970* [*History of Icelandic Trawling 1945–1970*]. Vol. 11. Sagnfrædirannsóknir, Studia Historica, ed. Gísli Gunnarsson. Reykjavík: Bókaútgáfa Menningarsjóds.
Pálsson, G. 1987. *Sambúd Manns og Sjávar* [*Fishing Adaptations*]. Reykjavík: Svart á hvítu.
Pálsson, G., and A. Helgason. 1995. Figuring Fish and Measuring Men: The Individual Transferable Quota System in the Icelandic Cod Fishery. *Ocean and Coastal Management* 28(1-3):117–46.
Scott, A.D. 1989. Conceptual Origins of Rights Based Fishing. *Rights Based Fishing.* P.A. Neher, R. Arnason, and N. Mollett, eds. Netherlands: Kluwer Academic Publishers.
Snævarr, S. 1993. *Haglysing Íslands* [*Icelandic Economic Development*]. Reykjavík: Heimskringla, Háskólaforlag Máls og Menningar.
Sydsaeter, K., and P.J. Hammond. 1995. *Mathematics for Economic Analysis.* Englewood Cliffs: Prentice-Hall.

Thorlindsson, T. 1988. The Skipper Effect in the Icelandic Herring Fishery. *Human Organization* 47(3):199–212.

___. 1994. Skipper Science: A Note on the Epistemology of Practice and the Nature of Expertise. *Sociological Quarterly* 35(2):329–45.

Townsend, R.E. 1992. Entry Restrictions in the Fishery: A Survey of the Evidence. *Land Economics* 66(4):359–78.

Wadel, C. 1972. Capitalization and Ownership: The Persistence of Fishermen-Ownership in the Norwegian Herring Fishery. *North Atlantic Fishermen: Anthropological Essays on Modern Fishing*. Andersen, R., and C. Wadel, eds. pp. 104–19. St. John: Memorial University Newfoundland Institute of Social and Economic Research.

Wilson, J.A., J.M. Acherson, M. Metcalfe, and P. Kleban. 1994. Chaos, Complexity and Community Management of Fisheries. *Marine Policy* 18(4):291–305.

Appendix

Municipalities, Investment in Fisheries, and Capital Transfers Received

Year	Municipality	Number of Inhabitants (1)	Investment 000 ISK (2)	Capital Transfers Received 000 ISK (3)	Gross Transfers Per Capita [(2)+(3)]/(1) ISK
1990	All municipalities	255,708	106,867	2,426	427.41
	Grindavík	2,172	2,280		1,049.72
	Sandgerdi	1,253	2,000		1,596.17
	Eyrarsveit	817	6,700	2,426	11,170.13
	Patreksfjördur	926	30,000		32,397.41
	Ólafsfjördur	1,171	3,418		2,918.87
	Gryturbakkahreppur	419	14,775		35,262.53
	N.Thingeyjarsysla	1,457	13,512		9,273.85
	Neskuapstadur	1,738	4,000		2,301.50
	Vopnafjördur	908	27,000		29,735.68
1991	All municipalities	259,577	28,128	13,001	158.45
	Keflavík	7,566	13,230	13,000	3,466.83
	Eyjafjardarsveit	1,676	1,207		720.17
	S.Thingeyjarsysla	1,752	1,090		622.15
	Neskuapstadur	1,681	9,999		5,948.25
	Eskifjördur	1,036	1,158		1,117.76
1992	All municipalities	262,193	74,115	80,850	591.03
	Bolungarvík	1,194		2,146	1,797.32
	Dalvík	1,505	1,500		996.68
	Seydisfjördur	898	65,000	71,780	152,316.26
	Vopnafjördur	888	1,840		2,072.07
	Höfn	1,744	500	6,378	3,943.81
1993	All municipalities	264,628	149,380		564.49
	Bolungarvík	1,163	30,000		25,795.36
	Pingeyri	499	6,015		12,054.11
	Ólafsfjördur	1,184	20,554		17,359.80
	Dalvík	1,533	7,950		5,185.91
	Seydisfjördur	879	25,000		28,441.41
	Vopnafjördur	886	3,500		3,950.34
	Stokkeyri	534	4,434		8,303.37

Source: Statistics Iceland, local govermental finances, various years.